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NORTHERN GOSHAWK  
INVENTORY AND MONITORING:  
DEVELOPING SAMPLING STRATA FOR THE  
COLORADO-WYOMING BIOREGION

**NORTHERN GOSHAWK INVENTORY AND MONITORING:  
DEVELOPING SAMPLING STRATA FOR THE COLORADO-WYOMING BIOREGION  
FINAL REPORT**

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**December 2003**

**OVERVIEW**

The northern goshawks (*Accipiter gentilis*) (hereafter called “goshawk”) is a forest-dwelling raptor thought to be adversely affected by changes in forest composition and structure due to forest management activities (e.g., logging, grazing, fire suppression). As a result, the USDA Forest Service (USFS) has designated the goshawk as a “sensitive” species in nearly all of its administrative regions within the hawk’s geographic range. A sensitive designation obligates Forest Supervisors to determine the distribution, status, and population trend of goshawks and their habitats on National Forest lands (FSM2670.45).

In April 2002, the USFS assembled a committee, hereafter called the Northern Goshawk Monitoring Committee (NGMC), to develop a technical guide describing how to inventory and monitor goshawks on National Forest System lands. The NGMC delineated 10 bioregions “based on differences in ecological conditions that could affect goshawk status and trend” (C. Hargis, pers. comm.) within which to apply the inventory and monitoring protocol. Within each bioregion, the protocol establishes a sampling framework, or grid, containing 1,700-ac cells designed to increase the efficiency of locating active goshawk nests. Each cell is referred to as a “primary sampling unit” (PSU). The sampling frame includes only PSUs containing “forested” habitat, i.e., those potentially occupied by goshawks -- non-forested areas are “not considered habitat.”

The NGMC technical guide designates forested habitat as (1) primary habitat, or habitat used by nesting goshawks and (2) marginal habitat, or habitat with little or no documented use by goshawks. These designations are further delineated by four sampling strata: 1) primary habitat, easily accessed, 2) primary habitat, difficult to access, 3) marginal habitat, easy to access, and 4) marginal habitat, difficult to access.

In March 2003, the NGMC requested a model for designating primary and marginal PSUs for an area identified as the “Colorado-Wyoming Bioregion.” This process evolved over the next several months, as preliminary modeling results were obtained, and as the goals of the NGMC were modified based on these results. The project involved outreach, data acquisition and standardization, advanced scripting for specialized GIS applications, data summary, the development, running, and testing of predictive spatial models, and the generation of final models (GIS grids) containing primary and marginal goshawk PSUs. This report describes the process used to develop the sample frame

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(primary and marginal habitat), presents the final models, and offers suggestions for designating primary and marginal habitat.

## LOGISTICS

This work was conducted by USFS Rocky Mountain Research Station, personnel (Research Wildlife Ecologist, Suzanne M. Joy) and Geoquantia (Spatial Analysts, Robin M. Reich and Vernon Thomas) as stated on Purchase Order 43-82FT-30162.

## STUDY AREAS

Although the NGMC technical guide was intended for all bioregions occupied by goshawks, initial application of the sampling strategy was limited to the Colorado-Wyoming bioregion of USFS administrative Region 2 (R2). The Colorado-Wyoming bioregion includes the Arapaho/Roosevelt, Grand Mesa/Uncompaghre/Gunnison, Medicine Bow/Routt, Rio Grande/San Juan, Pike San Isabel, and White River National Forests. The Arapaho and Roosevelt National Forest was removed from the modeling effort due to insufficient Goshawk locations. The study area included lands on both sides of the Continental Divide, where topography ranges from rolling hills to mountain peaks over 14,000 feet in above sea level. Landscapes include grasslands, alpine meadows, lakes, valleys, and forests.

## METHODS

### *Goshawk Locations*

Each Forest was asked to provide the location of goshawk nests know to be active within the past 10. These data were requested in Universal Transverse Mercator (UTM) coordinates (NAD83 datum) or Lat/Long coordinates (WGS84 datum). Lat/Long coordinates were reprojected to UTM coordinates. Data not received in either UTM or Lat/Long were reprojected UTM coordinates using ArcView<sup>®</sup> 3.2 (ESRI 1998). Coordinates received in the United States Public Land Survey Coordinate System were converted to UTM Zone 13 coordinates using a web-based Geographical Locator (<http://www.esg.montana.edu/gl/trs-data.html>).

### *Data Layers*

ArcView<sup>®</sup> Avenue (ESRI 1998) was used to generate a 2.62 x 2.62-km (1700-ac) cell polygonal grid that encompassed the entire study area and was clipped to the bioregion boundary. GIS surface grids of elevation, slope, aspect, and landform were derived from digital elevation models (1:24000, 30-m x 30-m spatial resolution; US Geological Survey) using ArcView<sup>®</sup> (ESRI 1998). Landform (McNab 1989) is an index that expresses surface shape as a measure of surface concavity (negative values) or convexity (positive values) creating a continuous variable surface. Landform was computed as the

mean slope gradient from the original cell to adjacent cells in 4 directions using ArcView<sup>®</sup> Avenue (ESRI 1998) code:

Vegetative information was obtained from the USFS for each forest in the form of Resource Information System (RIS) or Common Vegetation Unit (CVU) polygon coverages. These data included multiple descriptive variables of forest composition and structure, such as cover type species, percent cover of trees, shrubs and grass, habitat structural stage, and horizontal diversity. Each attribute was selected and converted to a separate grid.

### **Model 1**

We attempted to develop one model that would predict Goshawk nests throughout the bioregion. To do this, input variables for the model were limited to the number of attributes available for the Pike San Isabel National Forest. Only RIS data were available for this Forest, which contain fewer variables than CVU data. RIS and CVU variables derived from the various forests were standardized to common units.

Around each nest point, we generated a 2.62 x 2.62-km polygon (equivalent to a 1,700-ac PSU), centered on the nest point. All nest-based PSUs were contained in one grid surface. We derived average attribute information (topographic and vegetative) for each nest-based PSU and added it to the nest-PSU attribute table using custom ArcView<sup>®</sup> Avenue (ESRI 1998) code. Habitat attributes associated with each nest point were based on an average of the values completely surrounding the nest location.

To sample the range of topographic and vegetative variability on the study area, we generated a polygon coverage containing randomly-generated PSUs, with cells equivalent in number to the nest PSUs on each forest. The attribute table for the random-PSU coverage was then populated with average vegetative and topographic information as above. We then merged the nest-PSU and random-PSU attribute coverages and exported their merged table attributes to S-PLUS<sup>®</sup> (Statistical Sciences 2000).

In S-PLUS<sup>®</sup> (Statistical Sciences 2000), we generated a set of binary data for which nest PSUs were assigned a value of one and random PSUs a value of zero. We fit a logistic regression model to the data to describe the probability of observing a Goshawk nest site as a function of the independent variables. This was accomplished by fitting a generalized linear model with a logistic link. We also employed a general additive logistic model to identify curvilinear relationships and interactions between independent variables. We then generated analysis of deviance tables (ANOVA) to identify which variables should be included and/or excluded from the final model. Both backward and forward selection methods were used to choose the best subset of variables. To help evaluate this process, we generated graphical summaries.

Ten-fold cross-validation (Efron and Tibshirani 1993) was used to estimate the prediction accuracy of the final models. The data were split into  $K=10$  parts consisting of approximately the same number of sample points. For each part, the models were fitted

to the remaining  $K-1=9$  parts of the data. The fitted model was used to predict the part of the data removed from the modeling process. This process was repeated 10 times so that each sample point was excluded from the model fitting step and its response predicted. The prediction accuracy could then be inferred by comparing the predicted value with the actual value.

Using Arc Macro Language (AML; ARC/INFO®, ESRI 1995) and the CON command (CON; GRID Module), we generated a probability surface (grid) using the coefficients of the logistic regression model. To identify nest from random PSUs, a threshold probability value was selected that maximized the overall accuracy of correctly identifying nest and random PSUs. Probability values above the threshold were identified as nest PSUs and those below were identified as non-nest sites.

## Model 2

We modeled each forest separately, using the maximum number of habitat variables available on each forest. A unique PSU grid was generated for each forest by clipping the bioregional-level PSU grid with the extent of each forest + 3km (ArcView® Avenue; ESRI 1998). The larger boundary was used to ensure that PSUs at the forest boundary were not truncated. Each forest-based model used only nest points available on the forest. For modeling purposes, we also generated an equivalent number of random points to nests. To sample the topography and vegetation associated with each nest, we selected the PSU grid cell into which the each point (nest or random) fell, rather than generating a PSU centered on the point. These cells were then converted to a single ArcView® shapefile. Attribute tables of the nest and random PSU coverages were then populated with average vegetative and topographic information. We then merged the nest-PSU and random-PSU attribute tables, and exported the merged table to S-PLUS® (Statistical Sciences 2000).

The maximum number of habitat attributes sampled on any one forest included (1) habitat structure, (2) percent cover of dominant tree species, (3) overall percent tree cover, (4) mean elevation, slope, aspect and landform, (5) percent shrub, grass, forb, barren soil and water cover, (6) dominant tree species, (7) second dominant tree species, (8) third dominant tree species, (9) percent cover of first, second and third dominant tree species, (10) aspen presence (yes/no), and (11) total number of tree species in the PSU. Attributes relating to aspen habitat were thought to be important in identifying the dominant deciduous component of forests (C. Hargis, pers. comm.). Otherwise, the modeling steps were identical to those used in Model 1.

## RESULTS

### Model 1

The model generated for the entire bioregion had limited (30-50%) predictive success. The poor predictive ability of this model was attributed to three main factors: 1)

variables used in the model were limited to the attributes of the forest with the least amount of information, 2) over 50% of the sample points used to generate the model were “driven” by Goshawk nest locations on the Medicine Bow National Forest, an ecoregion physiographically and vegetatively distinct from the more southern forest lands, and 3) by creating nest and random PSUs that were centered around the nest and random points, and not aligned with the forest PSUs, the averaged statistical differences between the forest PSUs and the nest/random PSUs were too great to result in an accurate model.

## Model 2

Independent variables used for predicting Goshawk nest locations on the San Juan, Rio Grande, Medicine Bow/Routt, Grand Mesa/Uncompaghre/Gunnison, White River, and Pike San Isabel National Forest models (Tables 1- 6, respectively) included combinations of elevation, slope, aspect, landform, % tree cover, % grass cover, % of the dominant tree species, presence of aspen, and habitat structure. Some of these terms are represented as second-degree orthogonal polynomials and interactions. Estimated regression coefficients, standard errors, and partial t-test of their significance for the logistic models (Tables 1-6) reflected the relative contribution each variable made to the model.

Plots of the partial fits for the generalized additive logistic regressions for the San Juan, Rio Grande, Medicine Bow/Routt, Grand Mesa/ Uncompaghre/ Gunnison, White River, and the Pike San Isabel National Forests (Figs. 1, 3, 5, 7, 9, and 11) demonstrated how well each model fit the data through examination of the fit of each term in the model. These plots help to determine if linear or curvilinear relationships, or interaction terms between independent variables, should be used in the model.

Plots of the generalized linear models for the San Juan, Rio Grande, Medicine Bow/Routt, Grand Mesa/Uncompaghre/Gunnison, White River, and the Pike San Isabel National Forests (Fig. 2, 4, 6, 8, 10, and 12, respectively) allowed us to evaluate the fit of the logistic models. Systematic curvature in the residual plots (“Deviance Residuals” vs. fitted model) indicated that (1) an inappropriate link was chosen, (2) one of the predictors might be at the wrong scale, or (3) that a quadratic term in a predictor was omitted. Large residuals could also be detected using these plots, which may have required removal of an observation and re-fitting of the model.

Plots of the absolute residuals ( $\sqrt{\text{abs(Deviance Residuals)}}$ ) against predicted values provided a visual check of the adequacy of the assumed variance function, which had a binomial distribution. The Normal quantile plots were useful in detecting extreme observations that deviated from a general trend. While these types of graphs are generally useful in addressing the adequacy of a model, the residual plots are not very useful for binary data, because all of the points fall on one of two curves depending on whether the response is 0 or 1. Thus, one should exercise caution in not over-interpreting the meaning of the graphs.

Threshold values used to identify a PSU as a random or nest PSU ranged from a low of 0.43 for the White River and the Pike San Isabel National Forests to a high of 0.57 for the

Medicine Bow/Routt National Forest (Table 7). The Grand Mesa/ Uncompaghre/ Gunnison and the White River National Forests had the lowest overall prediction accuracy at 77%, while the Rio Grande National Forest had the highest overall prediction accuracy at 91%.

## CONCLUSIONS

The final models developed for the NGMC (Figs. 13-18) provide probabilities associated with predictions for the presence of active Goshawk nests on the forests sampled. These probabilities allow investigators to focus search efforts for nests into areas with a higher probability of success, when limited time for monitoring is available. Alternatively, model thresholds (Table 7) could be used to designate random from nest PSUs for more objective monitoring.

The probabilities associated with the PSU cells in each forest's model, as well as the threshold values designating nest from random PSUs, allow the investigator to identify primary and marginal Goshawk habitat. To identify "Goshawk habitat" (i.e., only forested areas), the investigator should first overlay the final grids (models) with the CVU or RIS data corresponding to each forest and select for forested areas only. Subsequently, nest PSUs may be designated as primary habitat and random PSUs as marginal habitat. Alternatively, the investigator may choose a probability level to use as a cutoff for primary and marginal habitat.

Although all models resulted in relatively high accuracies, prediction errors did occur. Sources of error may have included inaccurate nest coordinates, inaccuracies in the geo-referenced data (RIS, CVU) provided by the forests, or that the variables used in the model were inappropriate for the sampling design (i.e., use of PSUs). However, we attempted to minimize all sources of error.

Concurrent with the development of the sampling strategy described in this report, an initial application of the inventory and monitoring protocol was implemented on two National Forests within the bioregion, the San Juan and Rio Grande (C. Ferlund, pers. comm.). Model results were validated successfully with field observations (see C. Ferlund's M.S. Thesis for more information).

## ACKNOWLEDGEMENTS

We thank the many USFS regional and forest-level GIS specialists for their assistance in acquiring and interpreting CVU and RIS data. We also thank the National Forest Wildlife Biologists/Ecologists who provided coordinates for current and historic goshawk nests locations. Dan Greene, Jason Bennett, George Mayfield, Carol Tolbert, and Robert Skorkowsky were particularly helpful in interpreting vegetation codes or goshawk locational spreadsheets. Cheron Ferlund provided data for and valuable feedback on the San Juan and Rio Grande National Forest models. This feedback contributed significantly to success of the modeling process. Christina Hargis and Greg Hayward

facilitated data acquisition. Christina also provided regular feedback on the goals of the NGMC and suggestions for improving the models. Claudia Regan and Jennifer Ross provided regional vegetation layers used in earlier stages of the modeling process. Funding for this work was provided by the USDA Forest Service, Region 2 and the Rocky Mountain Research Station.

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Table 1. Estimated regression coefficients, their standard errors, and partial t-test of their significance for the logistic model for the San Juan National Forest, Colorado.

Variable	Coefficient	Standard Error	t-value
Intercept	-5.733	7.200	-0.796
Mean.elev	0.0032	0.003	1.079
Mean.slope	-0.632	0.267	-2.362
poly(Treecov, 2)1*	6.509	4.765	1.366
poly(Treecov, 2)2	-20.025	6.930	-2.889
poly(Mean.asp, 2)1*	16.374	7.178	2.281
poly(Mean.asp, 2)2	1.975	5.147	0.384
poly(Mean.lform, 2)1*	25.727	12.292	2.093
poly(Mean.lform, 2)2	-65.395	23.829	-2.744

\*Represents a second-degree orthogonal polynomial with respect to tree cover, aspect, and landform.

Table 2. Estimated regression coefficients, their standard errors, and partial t-test of their significance for the logistic model for the Rio Grande National Forest, Colorado.

Variable	Coefficient	Standard Error	t-value
Intercept	1.771	1.255	1.411
poly(Mean.elev, 2)1*	-28.023	8.208	-3.414
poly(Mean.elev, 2)2	-18.355	6.262	-2.931
Dom.habstr1Mgrasscov <sup>+</sup>	-0.098	0.050	-1.936
Dom.habstr3BGrasscov <sup>+</sup>	-0.248	0.113	-2.196
Dom.habstr3CGrasscov <sup>+</sup>	-0.263	0.185	-1.425
Dom.habstr4BGrasscov <sup>+</sup>	-0.249	0.096	-2.596
Dom.habstr4CGrasscov <sup>+</sup>	-0.161	0.133	-1.210

\*Represents a second-degree orthogonal polynomial with respect to elevation.

<sup>+</sup>Interaction term between dominant habitat structure and grass cover.

Table 3. Estimated regression coefficients, their standard errors, and partial t-test of their significance for the logistic model for the Medicine Bow/Routt National Forests, Colorado/Wyoming.

Variable	Coefficient	Standard Error	t-value
Intercept	-7.730	14.887	-0.519
TREE.COV	0.125	0.032	3.865
GRASS.COV	-0.298	0.119	-2.508
ASPEN.YN	10.283	14.835	0.693
MEAN.SLP	-0.294	0.098	-2.998
poly(MEAN.ELEV, 2)1*	5.881	9.756	0.603
poly(MEAN.ELEV, 2)2	-44.258	21.029	-2.104
DOM.CTPCT1	-9.749	2.153	-4.529

\*Represents a second-degree orthogonal polynomial with respect to elevation.

Table 4. Estimated regression coefficients, their standard errors and partial t-test of their significance for the logistic model for the Grand Mesa/ Uncompaghre/ Gunnison National Forest, Colorado.

Variable	Coefficient	Standard Error	t-value
Intercept	4.764	1.832	2.601
GRASS.COV	-0.207	0.102	-2.029
DOM.HABSTR2	-10.173	16.277	-0.625
DOM.HABSTR3	-1.594	0.906	-1.760
DOM.HABSTR4	-1.223	1.227	-0.996
DOM.HABSTR5	-9.743	60.437	-0.161
DOM.HABSTR6	0.001	1.037	0.001
DOM.HABSTR7	-1.409	1.626	-0.867
DOM.HABSTR8	7.044	60.437	0.116
DOM.CTPCT1	-3.983	2.237	-1.780

Table 5. Estimated regression coefficients, their standard errors and, partial t-test of their significance for the logistic model for the White River National Forest, Colorado.

Variable	Coefficient	Standard Error	t-value
Intercept	0.269	1.109	0.243
AVG.SLOPE	-0.178	0.076	-2.328
TREECOV	0.040	0.017	2.358

Table 6. Estimated regression coefficients, their standard errors, and partial t-test of their significance for the logistic model for the Pike San Isabel National Forest, Colorado.

Variable	Coefficient	Standard Error	t-value
Intercept	-6.943	60.434	-0.115
MEAN.SLOPE	-0.260	0.066	-3.914
DOM.HABSTR3	5.846	60.440	0.097
DOM.HABSTR4	6.753	60.452	0.112
DOM.HABSTR5	15.841	73.994	0.214
DOM.HABSTR6	15.338	69.335	0.221
DOM.HABSTR7	16.136	71.778	0.225
DOM.HABSTR10	7.253	60.436	0.120
ASPEN.YN	3.008	0.887	3.390

Table 7. Summary of the threshold values used to identify a PSU as a random or nest site along with classification accuracies for the National Forests participating in the National Goshawk Inventory and Monitoring modeling effort.

<b>National Forest</b>	<b>Threshold</b>	<b>Accuracy of Random PSUs</b>	<b>Accuracy of the nest PSUs</b>	<b>Overall Accuracy</b>
San Juan	0.54	0.886	0.853	0.869
Rio Grande	0.48	0.967	0.867	0.917
Medicine Bow/Routt	0.57	0.856	0.913	0.884
Grand Mesa/ Uncompaghre/ Gunnison	0.48	0.710	0.839	0.774
White River	0.43	0.654	0.889	0.773
Pike San Isabel	0.43	0.800	0.867	0.833

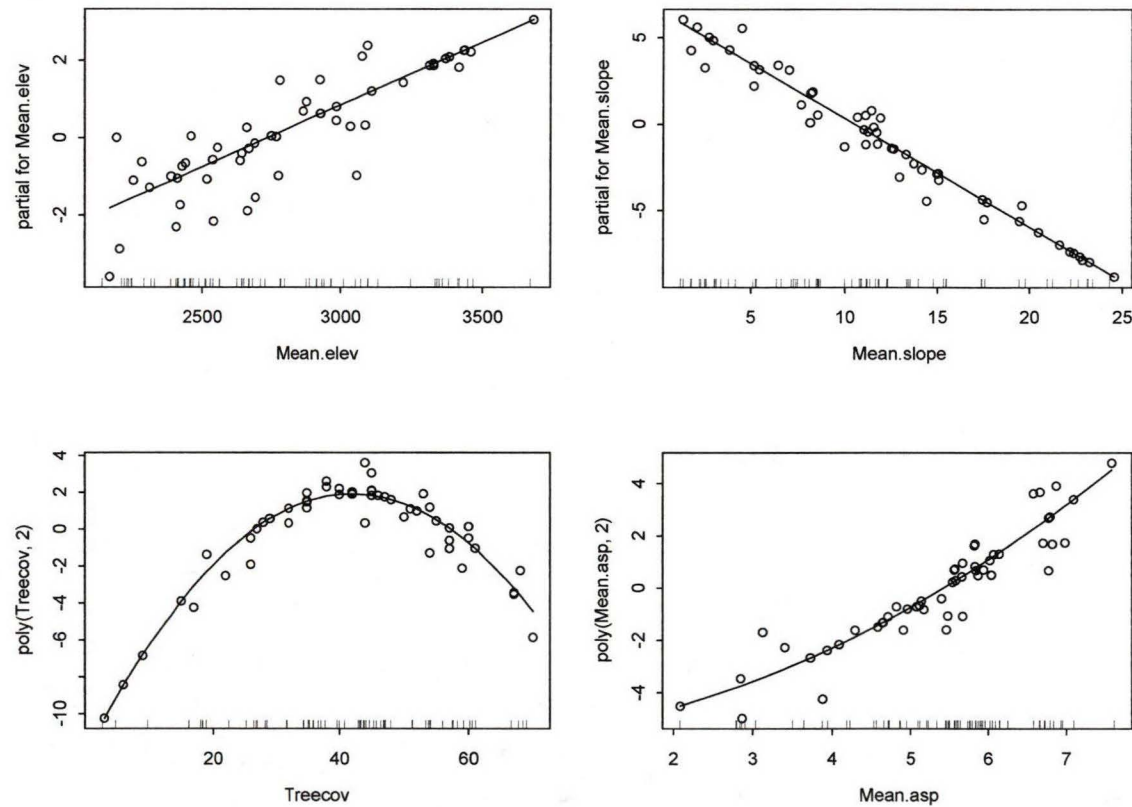


Figure 1. The partial fits for the generalized additive logistic regression for the San Juan National Forest, Colorado, with elevation, slope, tree cover, aspect, and landform as predictors.

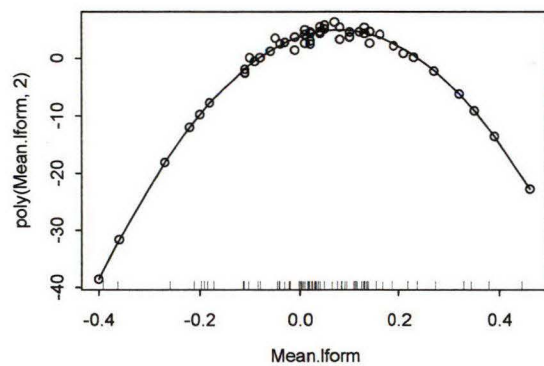


Figure 1. Continued.

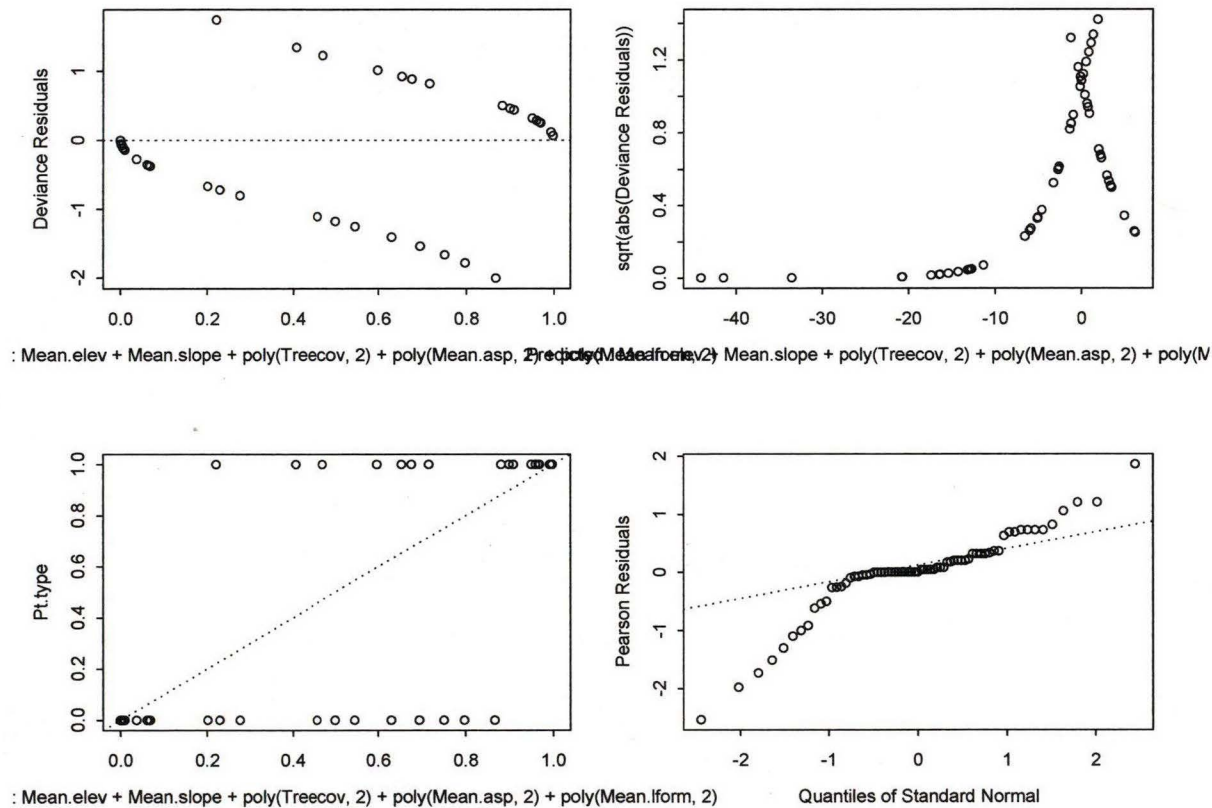


Figure 2. Plots of the generalized linear model for the San Juan National Forest, Colorado, predicted by elevation, slope, tree cover, aspect, and landform.

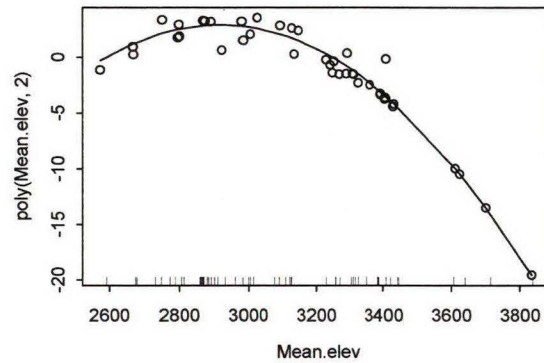


Figure 3. The partial fits for the generalized additive logistic regression for the Rio Grande National Forest, Colorado, with elevation as a predictor.

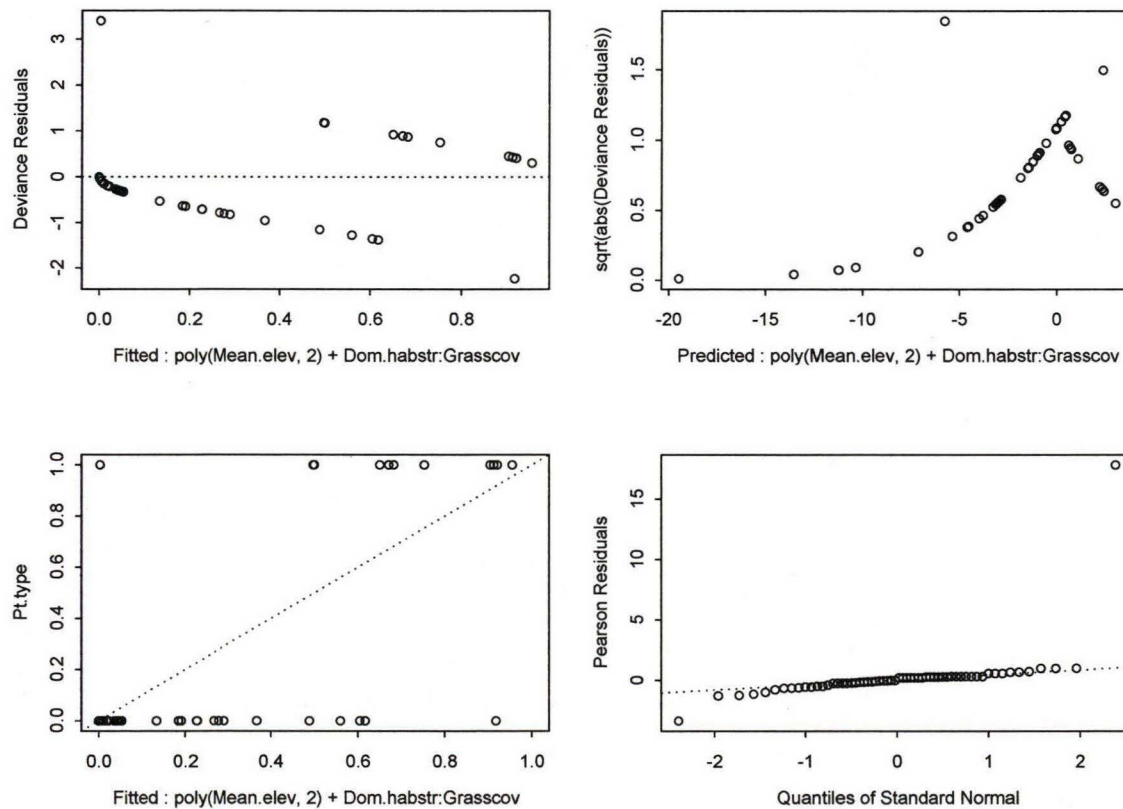


Figure 4. Plots of the generalized linear model for the Rio Grande National Forest, Colorado, predicted by elevation, habitat structure, and grass cover.

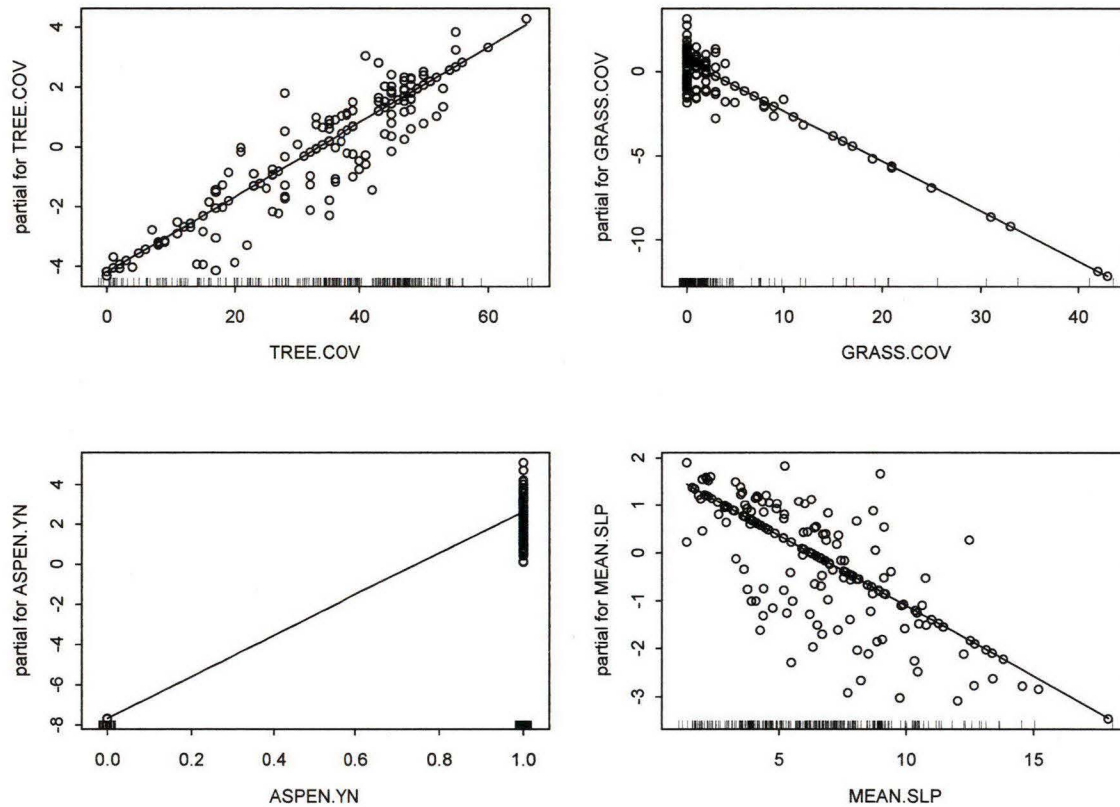


Figure 5. The partial fits for the generalized additive logistic regression for the Medicine Bow/Routt National Forests, Colorado/Wyoming, with tree cover, grass cover, presence/absence of aspen, slope, elevation, and dominant cover type as predictors.

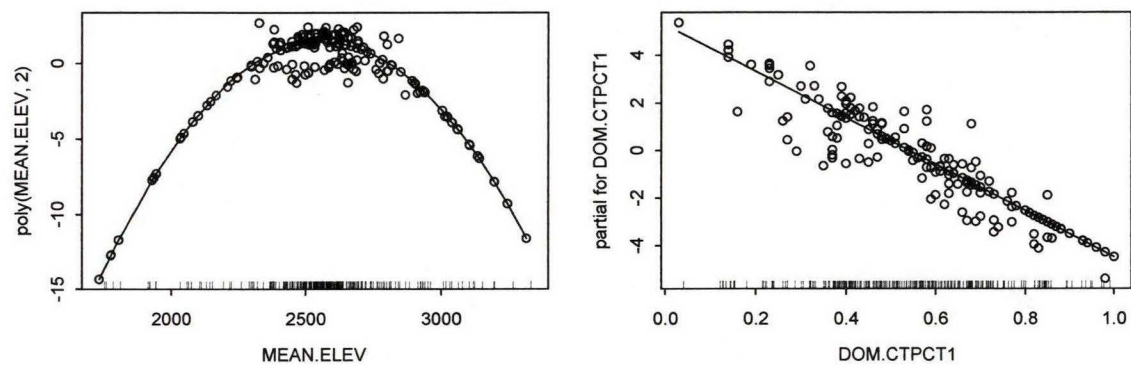


Figure 5. Continued.

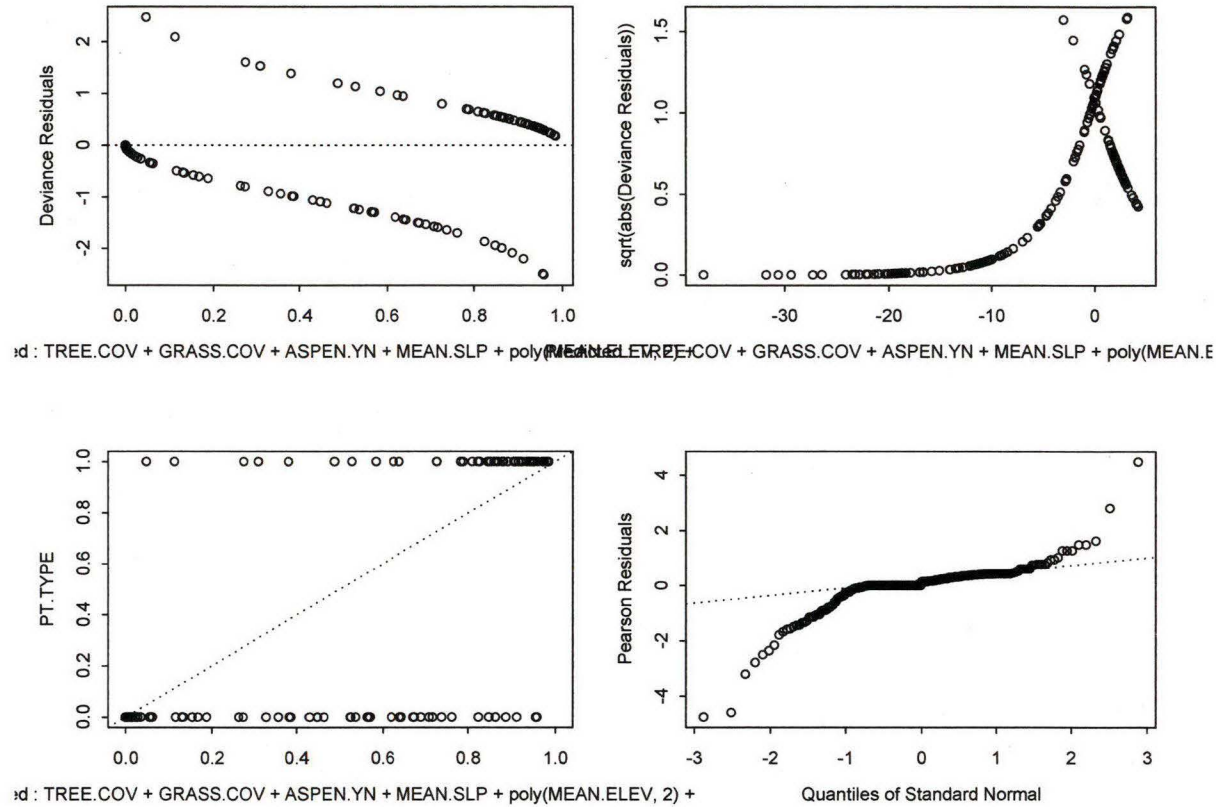


Figure 6. Plots of the generalized linear model for the Medicine Bow/Routt National Forest predicted by tree cover, grass cover, presence/absence of aspen, slope, elevation and dominant cover type

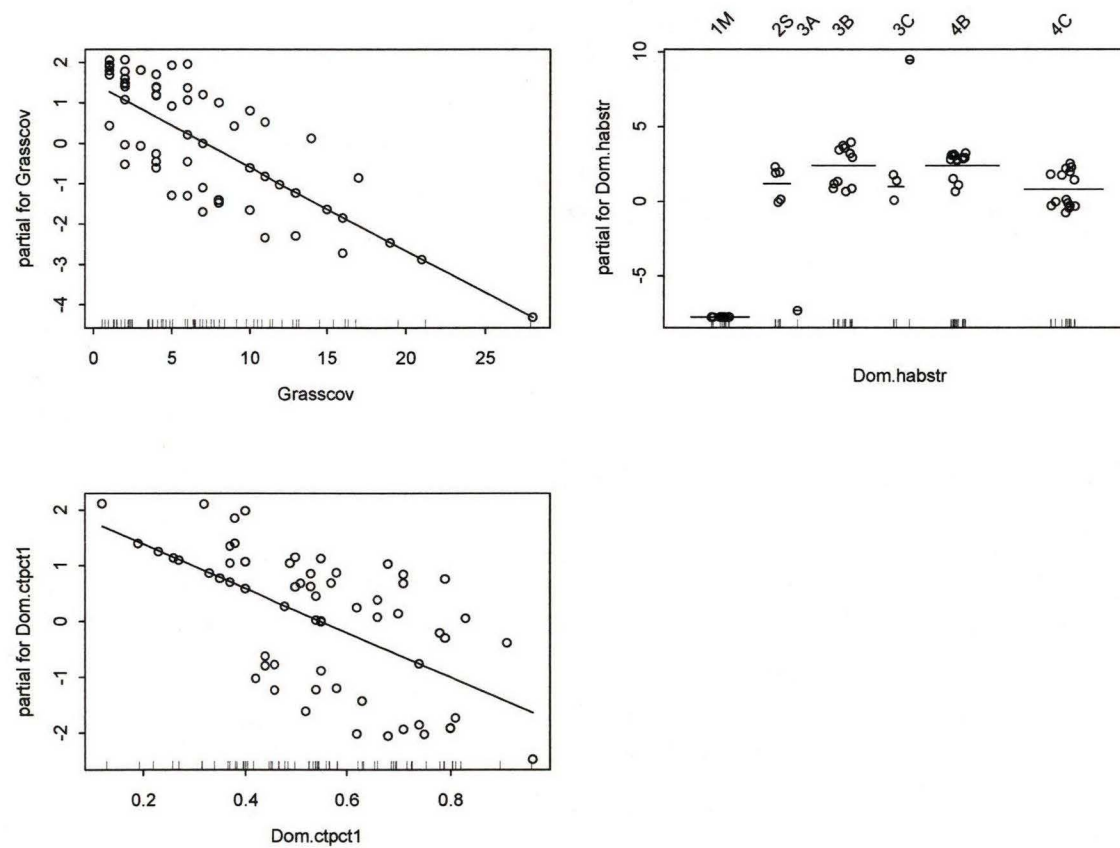


Figure 7. The partial fits for the generalized additive logistic regression for the Mesa/ Uncompaghre/ Gunnison National Forest with grass cover, dominant habitat structure, and dominant cover type as predictors.

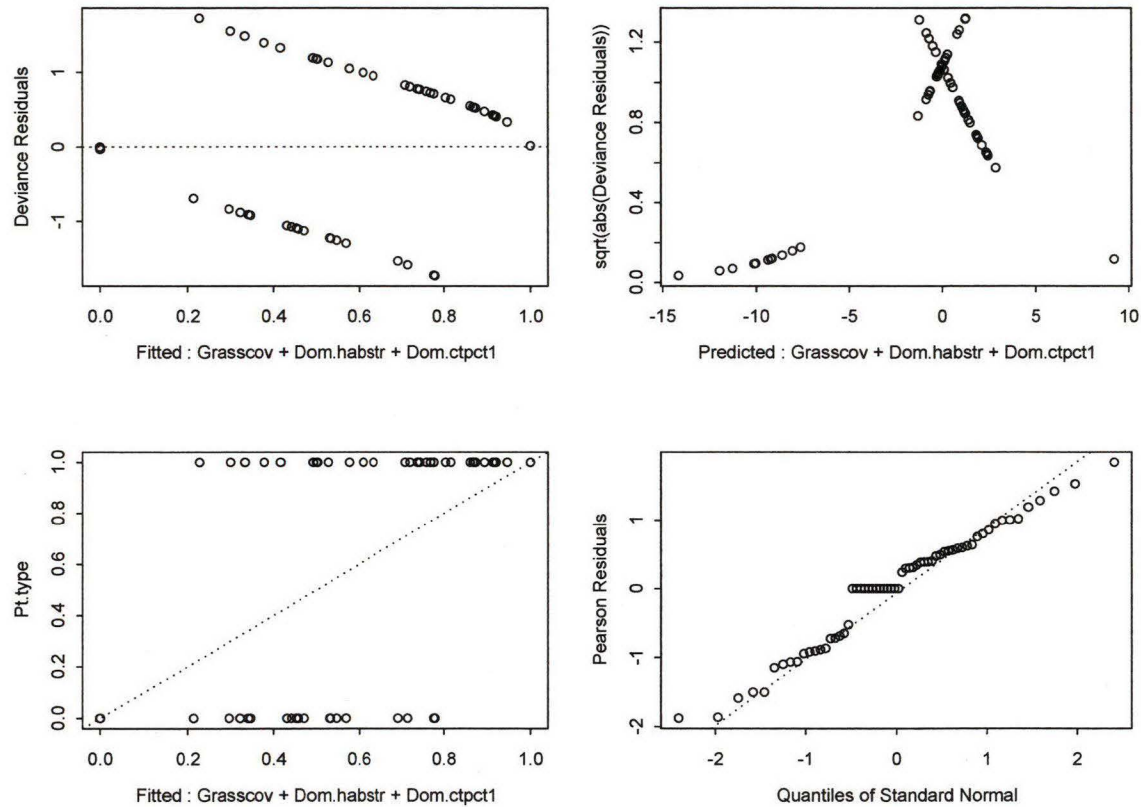


Figure 8. Plots of the generalized linear model for the Mesa/ Uncompaghre/ Gunnison National Forest predicted by grass cover, dominant habitat structure and dominant cover type.

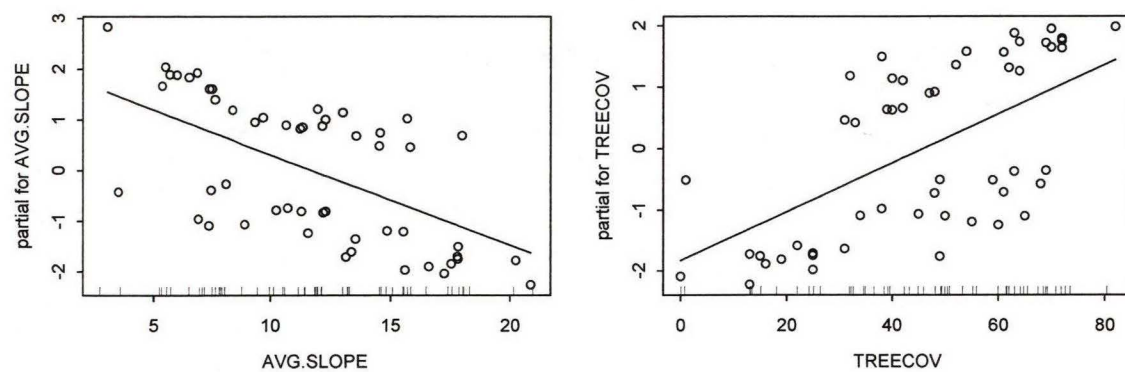


Figure 9. The partial fits for the generalized additive logistic regression for the White River National Forest with slope and tree cover as predictors.

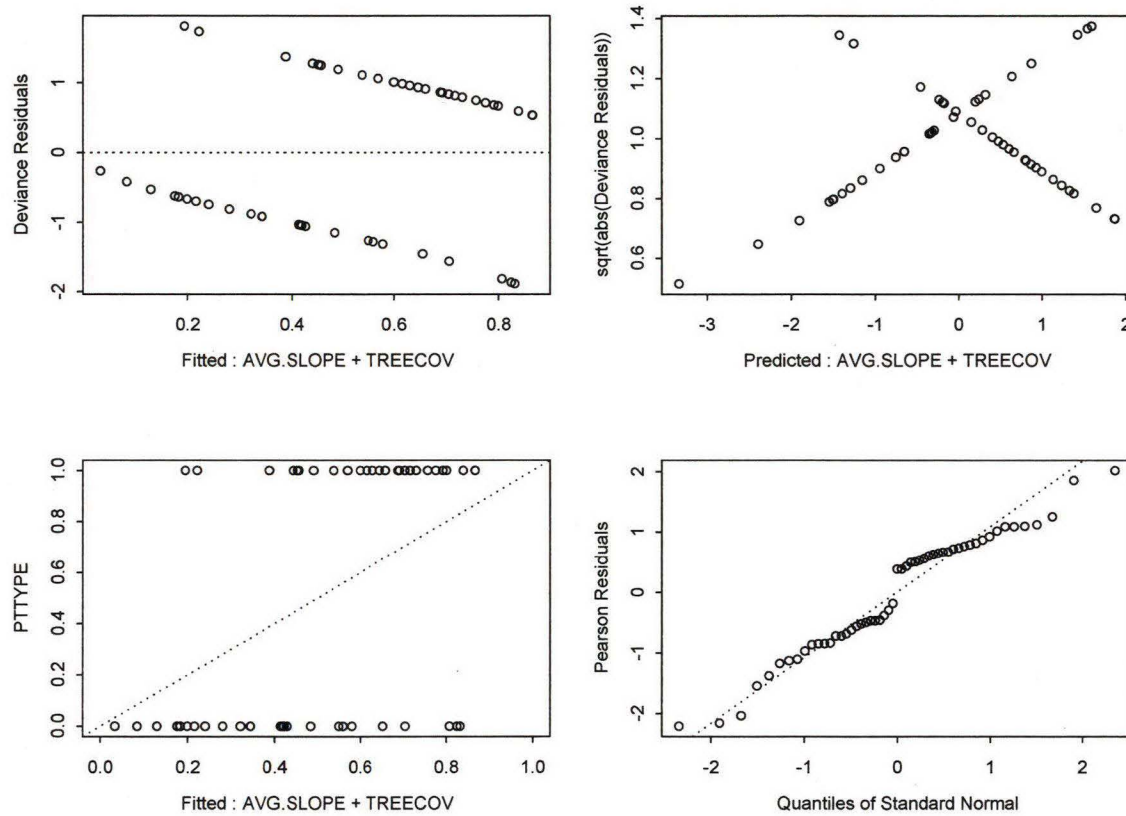


Figure 10. Plots of the generalized linear model for the White River National Forest predicted by slope and tree cover.

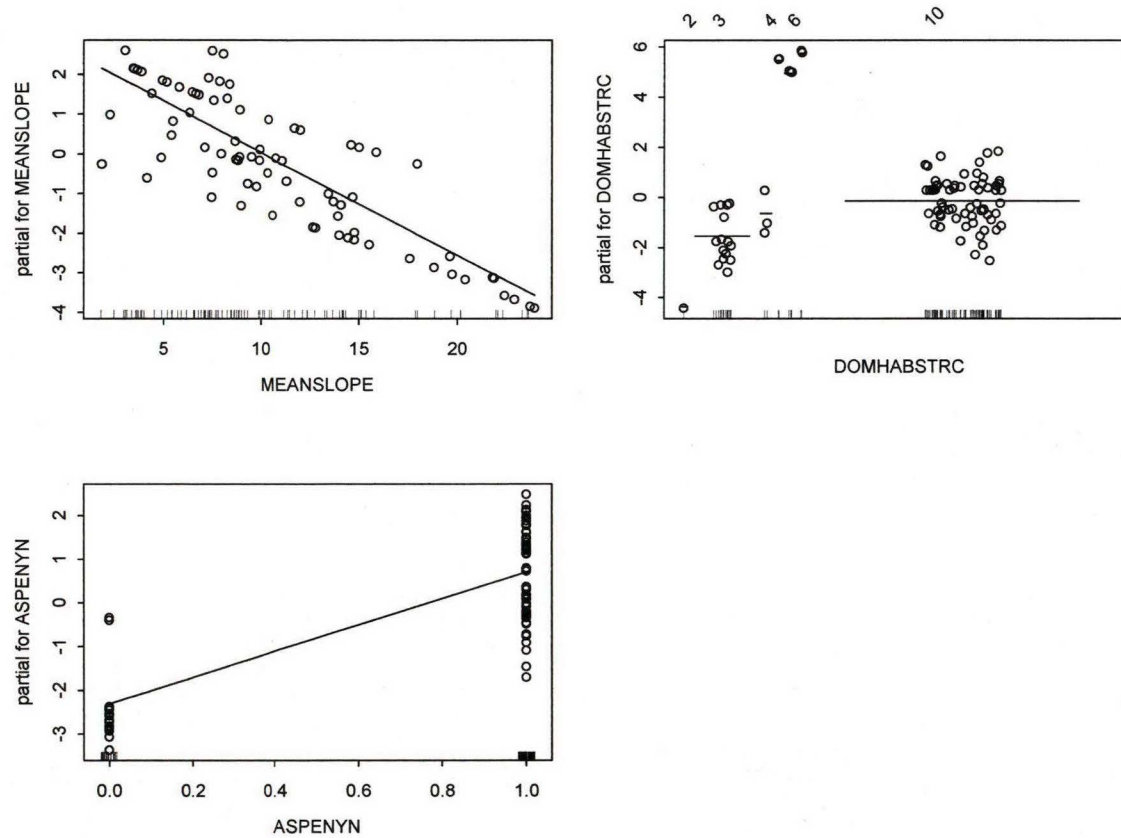


Figure 11. The partial fits for the generalized additive logistic regression for the Pike San Isabel National Forest with slope, dominant habitat structure and presence/absence of aspen as predictors.

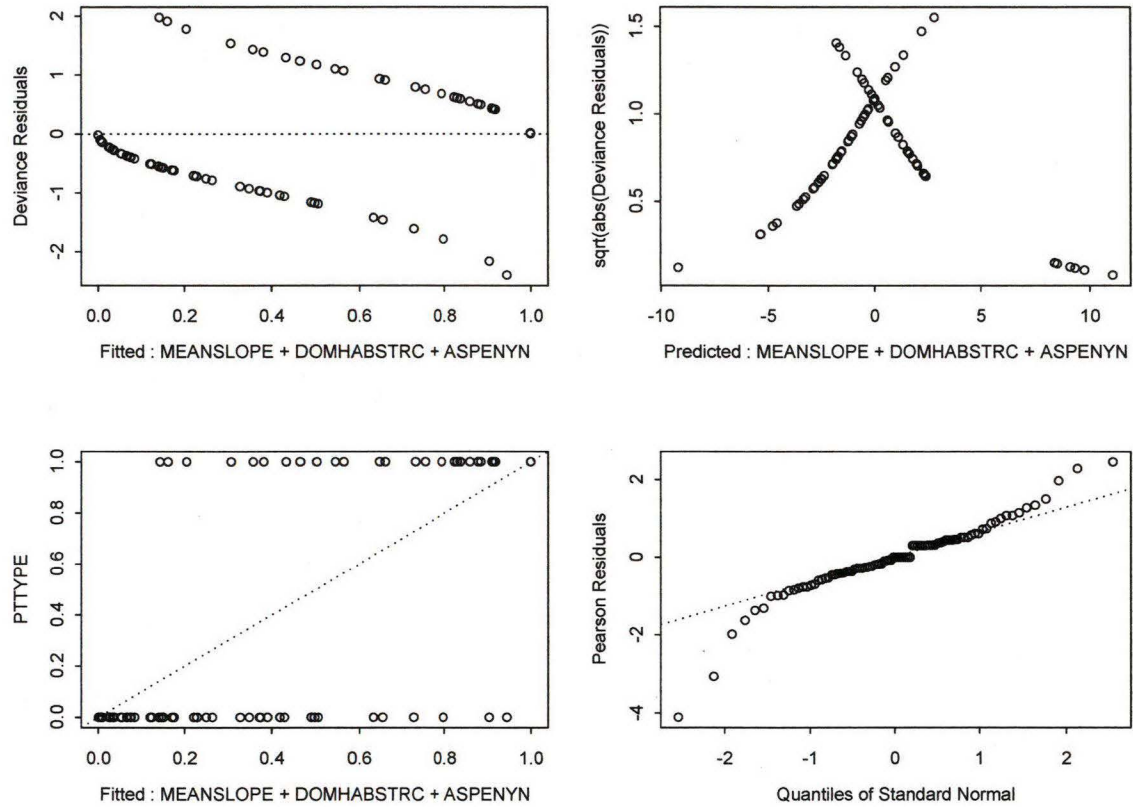


Figure 12. Plots of the generalized linear model for the Pike San Isabel National Forest predicted by slope, dominant habitat structure and presence/absence of aspen.

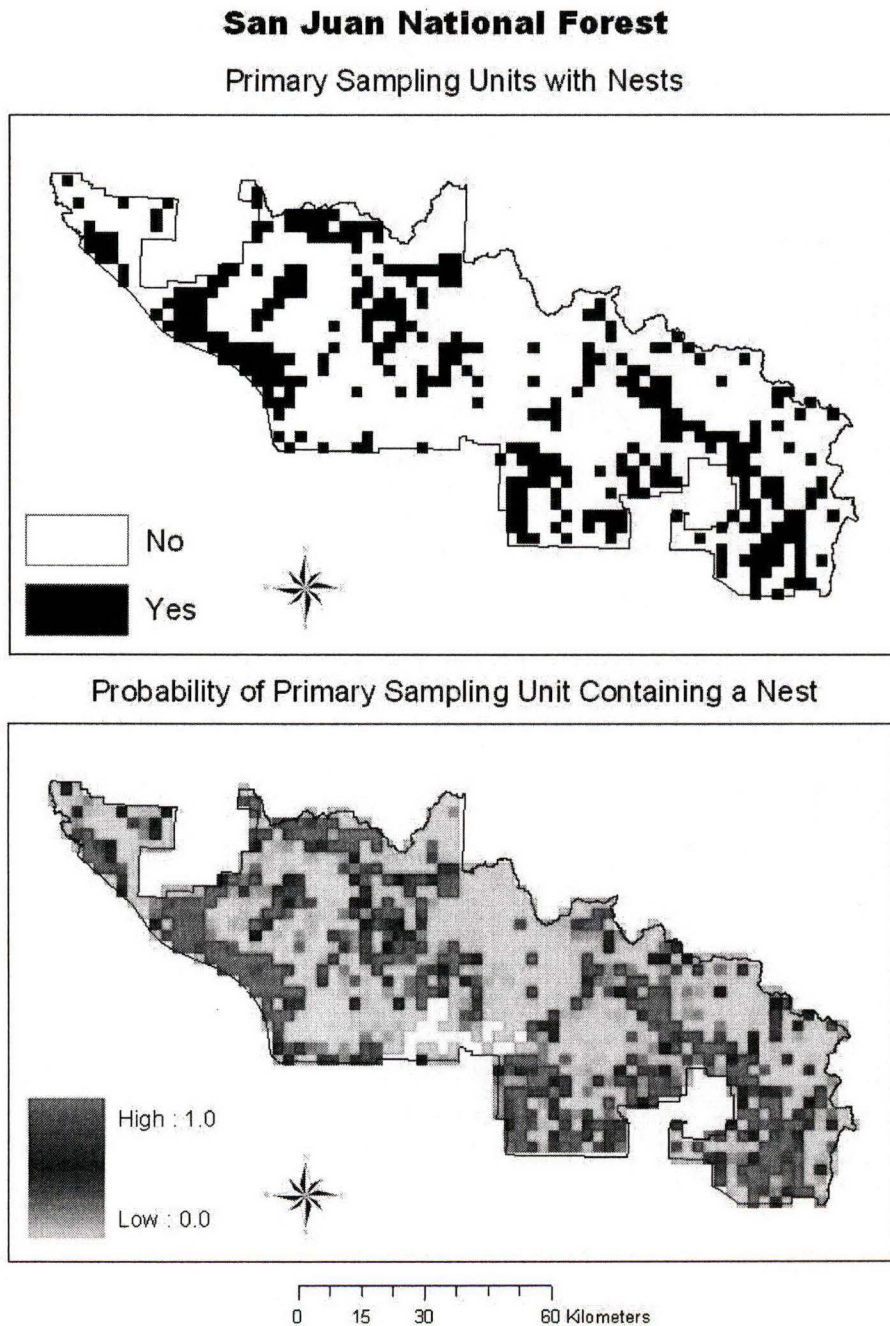


Figure 13. Location of 1,700-ac Primary Sampling Units (PSUs) containing active Northern Goshawk nests between 1992 and 2002 (top) and the probabilities associated with finding additional active nests on the PSUs (bottom) for the San Juan National Forest, Colorado. White areas within the forest boundary on the lower figure represent private land ownership.

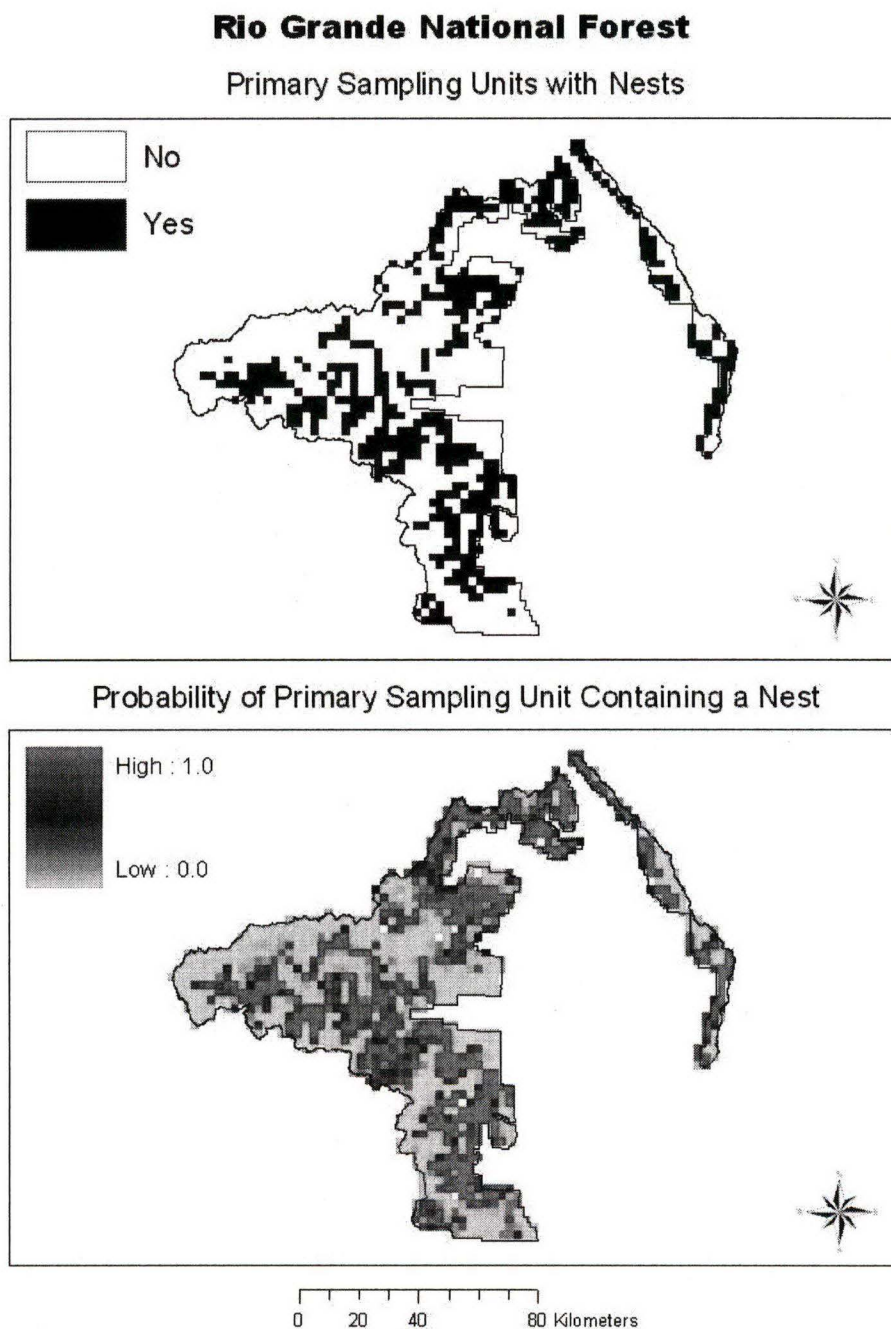


Figure 14. Location of 1,700-ac Primary Sampling Units (PSUs) containing active Northern Goshawk nests between 1992 and 2002 (top) and the probabilities associated with finding additional active nests on the PSUs (bottom) for the Rio Grande National Forest, Colorado. White areas within the forest boundary on the lower figure represent private land ownership.

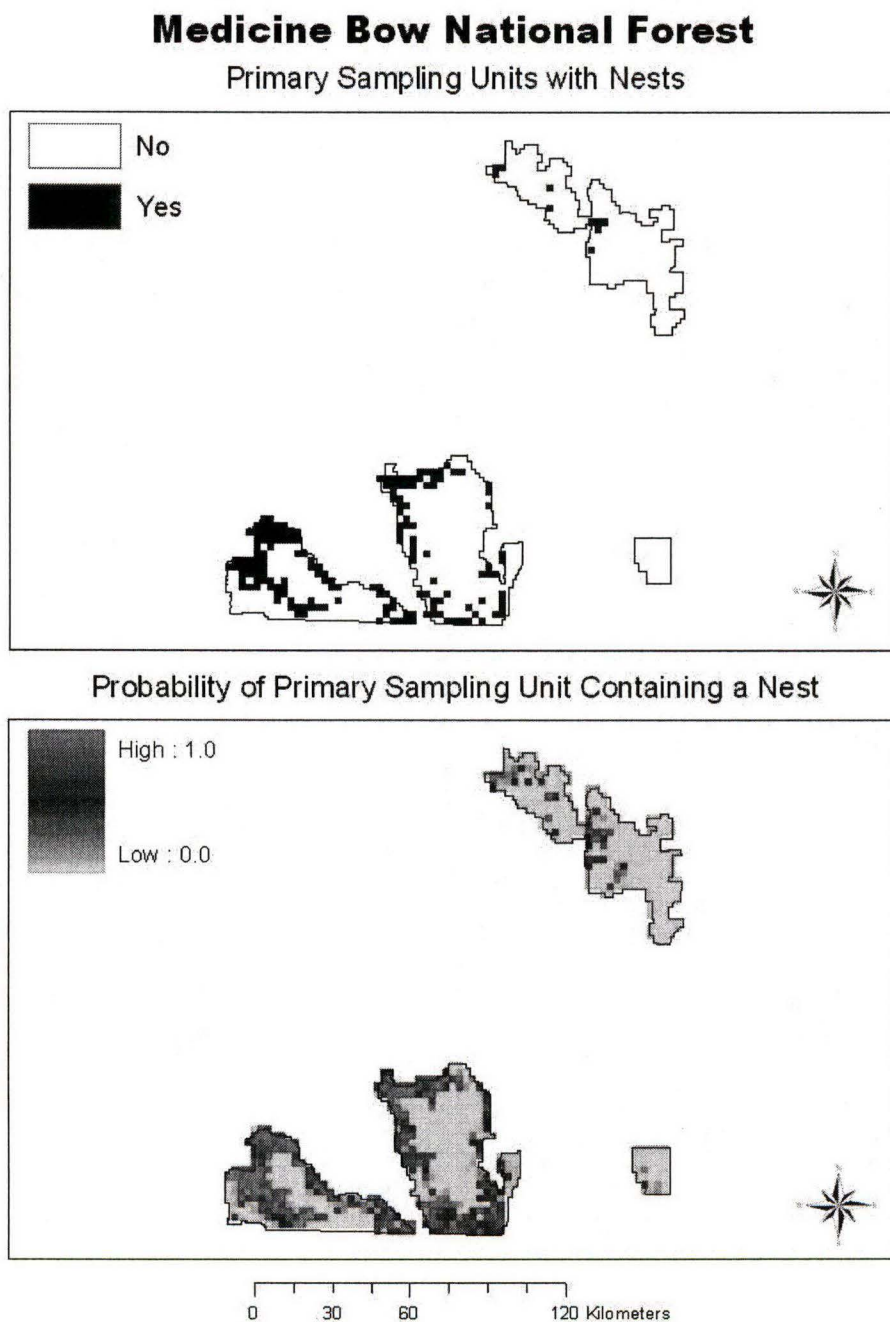


Figure 15. Location of 1,700-ac Primary Sampling Units (PSUs) containing active Northern Goshawk nests between 1992 and 2002 (top) and the probabilities associated with finding additional active nests on the PSUs (bottom) for the Medicine Bow National Forest, Wyoming.

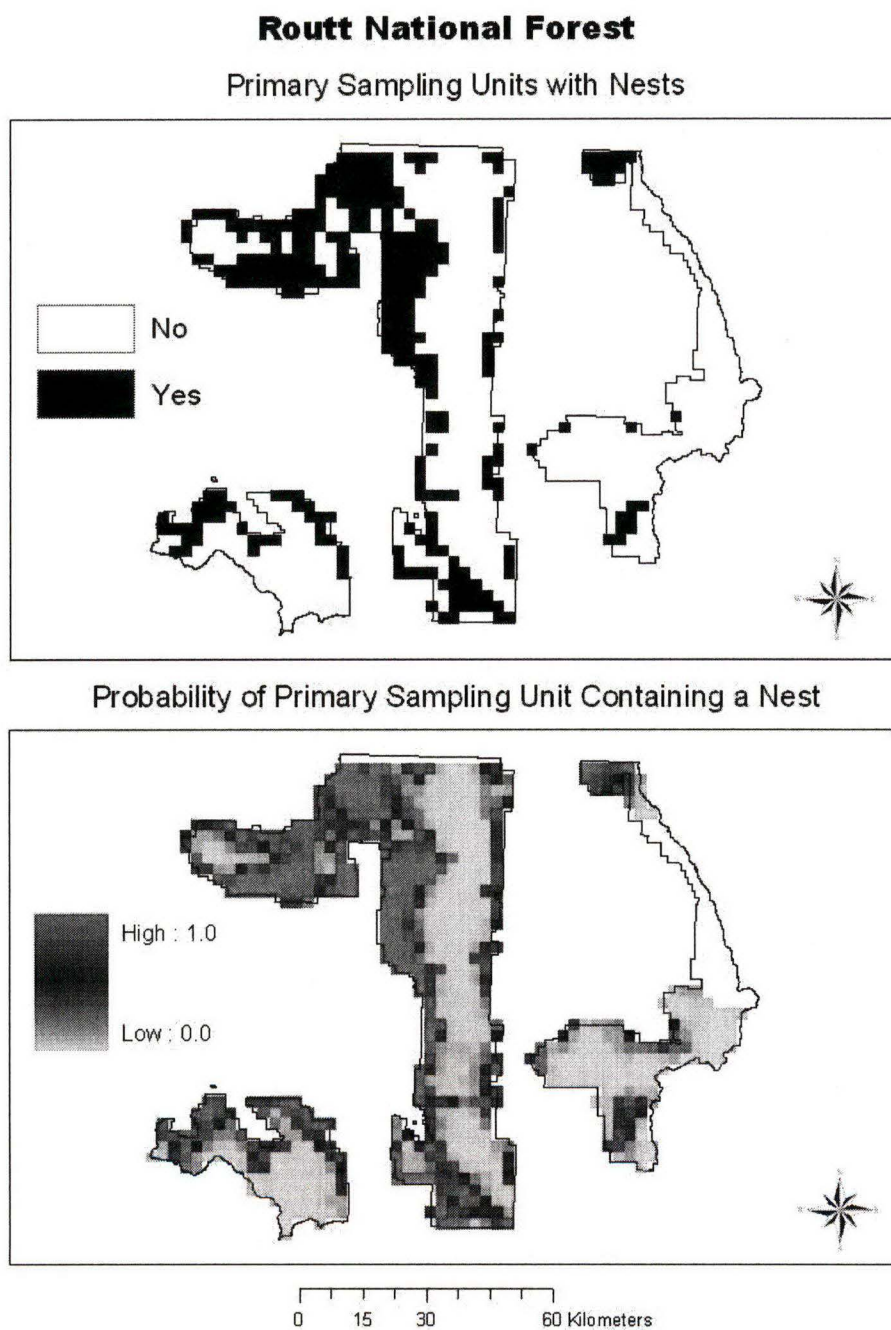
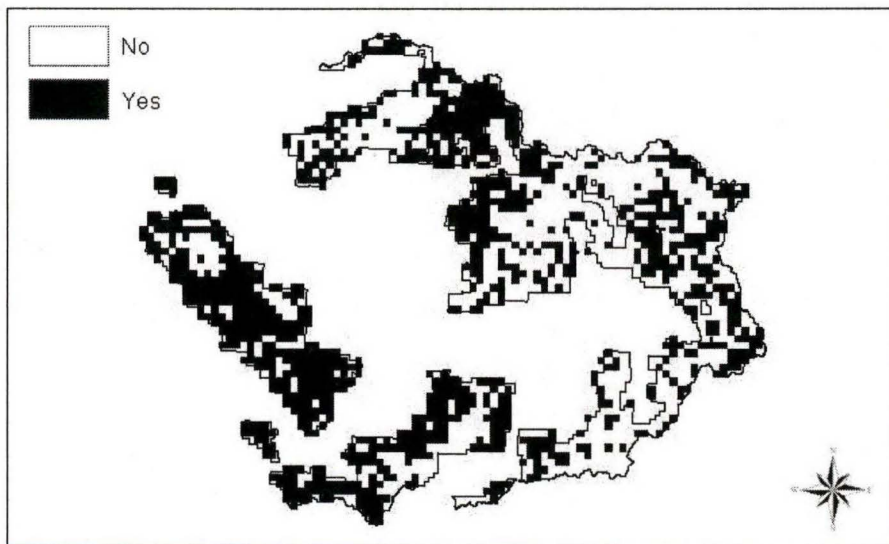


Figure 16. Location of 1,700-ac Primary Sampling Units (PSUs) containing active Northern Goshawk nests between 1992 and 2002 (top) and the probabilities associated with finding additional active nests on the PSUs (bottom) for the Routt National Forest, Colorado. White areas within the forest boundary on the lower figure represent private land ownership.

## Grand Mesa/Uncompaghre/Gunnison National Forests

### Primary Sampling Units with Nests



### Probability of Primary Sampling Unit Containing a Nest

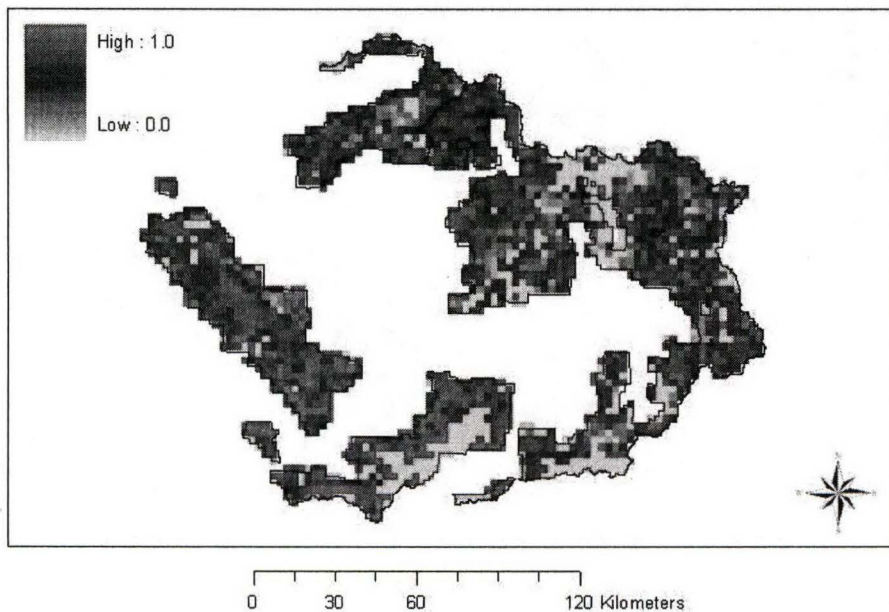


Figure 17. Location of 1,700-ac Primary Sampling Units (PSUs) containing active Northern Goshawk nests between 1992 and 2002 (top) and the probabilities associated with finding additional active nests on the PSUs (bottom) for the Grand Mesa, Uncompaghre, and Gunnison National Forests, Colorado. White areas within the forest boundary on the lower figure represent private land ownership.

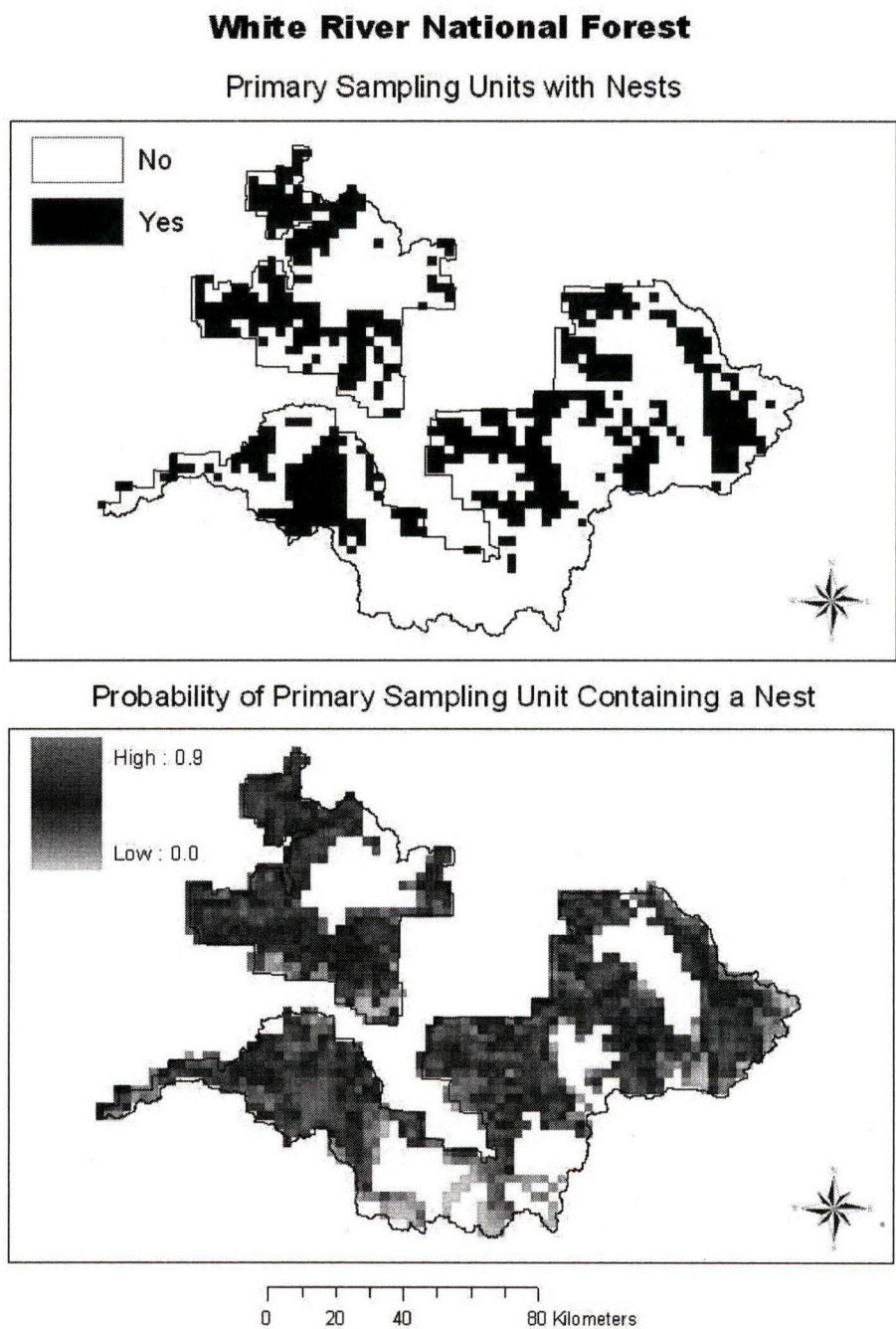


Figure 18. Location of 1,700-ac Primary Sampling Units (PSUs) containing active Northern Goshawk nests between 1992 and 2002 (top) and the probabilities associated with finding additional active nests on the PSUs (bottom) for the White River National Forest, Colorado. White areas within the forest boundary on the lower figure represent private land ownership.